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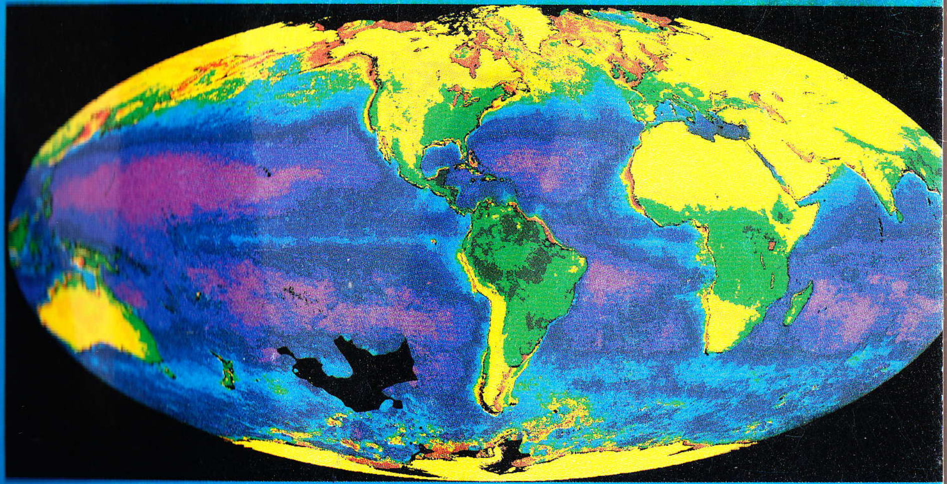
A Framework for Research on the Human Dimensions of Global Environmental Change



Harold K. Jacobson and Martin F. Price
for the ISSC Standing Committee
on the Human Dimensions of Global Change

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PREFACE

The International Social Science Council's interest in the human dimensions of global environmental change dates from the Sixteenth General Assembly in December 1986. A resolution adopted at this Assembly created an *ad hoc* committee to explore the possibility of developing an international social science research programme that would parallel and complement the International Geosphere-Biosphere Programme: A Study of Global Change (IGBP) of the International Council of Scientific Unions (ICSU), for it was clear that human activities had become a significant force in global change.

The ISSC joined IFIAS and UNU in sponsoring a meeting held in Toronto, Canada in June 1987 on the human response to global change. This meeting decided that the Tokyo International Symposium should be held, and created an Interim Steering Committee to plan the Symposium. Members of ISSC organized and took part in various workshops that were held prior to the Tokyo International Symposium. These workshops began to define an agenda for an international social science research programme on the human dimensions of global environmental change.

Acting on the basis of a proposal submitted by the Council's *ad hoc* committee, the Seventeenth General Assembly of the International Social Science Council decided to create a Standing Committee on Human Dumensions of Global Change. The committee, under the chairmanship of Professor H. Jacobson, was composed of representatives of social science disciplines from different regions of the world. It has met three times since its establishment. Its main task has been to draft the present *Framework for Research on the Human Dimensions of Global Environmental Change* which is to be discussed and endorsed at the forthcoming Eighteenth General Assembly of ISSC in November 1990.

The ISSC and the Standing Committee have encouraged the ISSC Member Associations, covering the whole spectrum of social sciences, to establish Research Committees or Working Groups on Global Change. A network of eleven such groups is now in existence and collaborative studies are to be undertaken.

The framework for research presented here attempts to present a coherent programme of international and interdisciplinary research on the human dimensions of global environmental change, and to complement natural science research on changes in the Earth's physical, chemical and biological systems carried out by the International Geosphere-Biosphere Programme of the International Council of Scientific Unions.

The International Social Science Council would like to express its deep appreciation to all members of the Standing Committee and in particular to its Chairman, Professor H. Jacobson, as well as to Dr. Martin Price. It is thanks to their vision and grasp of the issues involved in the human dimensions of global environmental change, and to their continued and constructive collaboration through successive versions of the text, that we owe the publication of the Framework.

The Centre National de la Recherche Scientifique of France, the Deutsche Forshungsgemeinschaft of Germany, the Economic and Social Research Council of the United Kingdom, the National Science Foundation of the United States, the Norwegian Research Council for Science and Humanities, the Social Sciences and Humanities Research Council of Canada and the Social Sciences and Humanities Research Council of Sweden provided funds to support the work of the Standing Committee. The International Social Science Council is deeply grateful for their assistance.

The ISSC also thanks Unesco for its extensive and insightful support of the ISSC's programme of Human Dimensions of Global Change.

International Social Science Council

Paris, July 1990

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A framework for research on the human dimensions of global environmental change

EXECUTIVE SUMMARY

It is widely recognized that human activities have substantial, cumulative and accelerating effects on the total earth system and the physical environment that it provides for life, yet this interaction is not well understood. Greater knowledge about this phenomenon is essential for long-term sustainable use of the Earth's systems. The framework for research proposed in these pages provides a broad orientation for studies to generate such knowledge on the human dimensions of global environmental change.

Research on this topic must consider human activities both as they contribute to and as they are affected by global environmental change. The human activities that interact with the Earth's natural systems are driven by three fundamental factors: the number of human beings and their distribution around the globe; human needs and desires, as conditioned by psychological, cultural, economic, and historical factors, which provide individuals and societies with motivations to act; and the cultural, social, economic, and political structures and institutions and norms and laws that shape and mediate their behavior.

These factors can be encompassed within three broadly defined research topics: the social dimensions of resource use; the perception and assessment of global environmental conditions and change; and the impacts of local, national, and international social, economic, and political structures and institutions on the global environment. Each of these topics must be investigated separately. In addition, they must be investigated in combination as they interact in specifically defined contexts where human activities have a direct impact on the physical, chemical, and biological processes that are involved in global environmental change. Such research must be conducted at all geographical scales and should include the past as well as the present and the future.

Our framework for research proposes studies on the following seven topics: (1) social dimensions of resource use; (2) perception

and assessment of global environmental conditions and change; (3) impacts of local, national, and international social, economic, and political structures and institutions; (4) land use; (5) energy production and consumption; (6) industrial growth; and, (7) environmental security and sustainable development.

Research undertaken to serve this urgent global need will require conceptual, theoretical, and methodological development in the social sciences, both within disciplines and through the expansion of existing interdisciplinary fields of enquiry and the creation of new ones. Collaboration among social scientists and between social and natural scientists and cognizance of world-wide interconnections among the phenomena studied will be essential in order to deal with the crucial issues involved in global environmental change.

The challenges of understanding the human dimensions of global change are daunting. The urgency of gaining such understanding demands that the social sciences take up and meet these challenges.

I The need for research on the human dimensions of global environmental change

It is widely recognized that human activities have substantial, cumulative, and accelerating effects on the total Earth System and the physical envirnment that it provides for life, yet this interaction is not well understood. To improve understanding of this phenomenon, there must be concerted social science research. Greater knowledge is essential for long-term sustainable use of the Earth's systems. This document sets forth a framework to guide and orient research that would provide knowledge on the human dimensions of global environmental change.

The development of science and technology and their application throughout the world, especially in the twentieth century, have been the major driving force behind the increasing effects of human actions on the global environment. This phenomenon has made possible industrial and economic growth; rapid increases in rates of population growth, urbanization, migration, and life expectancy; and the internationalization of production.

Since 1950, the world's population has doubled. The demand for energy has quadrupled in the same period. Global economic growth, including intensive farming and increased use of natural resources, has catered for the culturally- and historically-shaped needs and desires of much of this burgeoning population and has vastly improved material conditions of life for many. Yet economic growth has not been uniform throughout the world, nor has it resolved the substantial disparities in material conditions which persist both within and among states and even communities. In fact, it has often exacerbated these disparities.

At the same time, demographic, economic, cultural, and technological driving forces have altered, and continue to alter, components of the Earth's physical, chemical, and biological systems and the interactions among them. Some of these changes may have serious consequences for the future habitability of the Earth through the processes of global environmental change, especially

because many of these changes are occurring at rates unprecedented in human history. These changes could threaten life and cause or intensify conflict. Moreover, global environmental change could accelerate even more rapidly as the world's population continues to grow and as people throughout the world, especially in developing countries, seek and achieve improved standards of material welfare.

Global environmental change may be divided into two types of processes: those that take place throughout a global system, including modifications of the climate system as a result of the build-up of "greenhouse gases" and the depletion of the stratospheric ozone layer; and those that take place across the globe, such as loss of agricultural land through desertification, loss of biodiversity, and increases in acid deposition.

Considerable progress has been made, especially over the past two decades, in understanding the functioning of the Earth's physical, chemical, and biological systems. Much of this progress has resulted from international scientific research activities. Foreseeable advances in the fields of remote sensing and computing hold promise for dramatically enhancing this understanding. Greater knowledge about the Earth's systems is critical for assessing the role of human activities as agents of change in these systems and the impacts of these changes on human life.

Although human interactions with the Earth's systems have been studied by social scientists in the past, the accelerating and cumulative impacts of human activities on the Earth's systems and the consequences of the likely resultant changes urgently demand that increased attention be devoted to this subject. Research in this field will benefit from the expanded research programs that have been launched in the natural sciences, the growing availability of societal data, and increases in computational capacity. It should yield knowledge essential for long-term sustainable use of the Earth's systems.

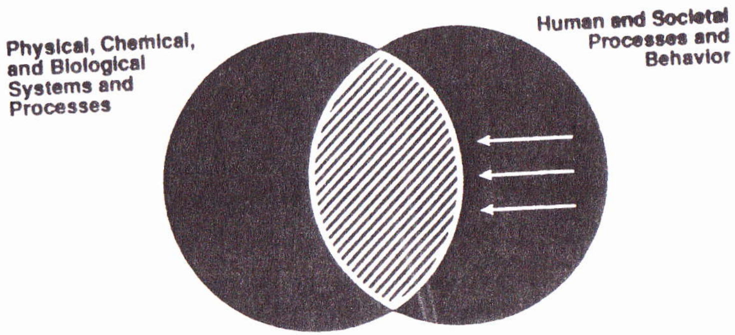
This Framework for Research provides a broad orientation for research on the human dimensions of global environmental change. Research undertaken on this topic will require conceptual, theoretical, and methodological development in the social sciences, both within and across disciplines and through the creation of new fields of study. Collaboration among social scientists and between social and natural scientists and cognizance of world-wide inter-

connections among the phenomena studied will be essential in order to deal with the full range of issues involved in global environmental change. These issues involve the environmentally significant behavior of human populations as shaped and mediated by culture and by social, economic, and political structures and institutions at local, national, and international scales as causal factors in global environmental change. They also involve the effects of global environmental change, both actual and perceived, on human populations and on their attitudes and behavior.

Figure 1 illustrates the relationship between the research topics proposed in this Framework for Research and the ongoing natural science research on global environmental change. Research on the human dimensions of global environmental change must deal both with those aspects of human behavior that directly interact with the Earth's physical, chemical, and biological processes (the overlapping area of the two spheres) and those human and societal processes that affect this behavior (selected aspects of the sphere on the right). Thus such human and societal phenomena as the evolution of cognitive processes and public opinion, changing tastes and life styles, disparities in the distribution of income within and among states, rising educational levels, and democratization must be considered as they influence human behavior that has impacts on the global environment.

Figure 1.

Relationship Between HDGEC and Ongoing Natural Science Research on Global Environmental Change



Human activities that interact with the Earth's natural systems are driven by three fundamental factors: the number of human beings and their distribution around the globe; their needs and desires - as conditioned by psychological, cultural, economic, and historical factors - which provide their motivations to act; and the cultural, social, economic, and political structures and institutions and norms and laws that shape and mediate their behavior. Consequently, research on the human dimensions of global environmental change must consider human behavior in relation to three broad themes: the social dimensions of resource use; the perception and assessment of global environmental conditions and change; and the impacts of local, national, and international social, economic, and political structures and institutions on the global environment. Such research must be conducted at all geographical scales and should include the past as well as the present and the future.

The social dimensions of resource use encompasses both demographic trends and interactions of population, economic growth, technology, and resource use. Demographic changes are a driving force in bringing about global environmental change. The size of the world's population, its characteristics, and its geographic distribution affect economic, social, and technological changes and are, in turn, affected by them. These interactive processes affect the use of land, water, air, energy and other renewable and non-renewable resources.

The perception and assessment of global environmental conditions and changes by governmental policy makers, managers of industrial enterprises, and societal groups of all sizes fundamentally affect how they react to and behave toward these conditions and changes. Individuals' assessment and perception of global environmental change will be influenced by many interacting factors, including their individual attributes, their cultural background, their social, economic, and political setting, and the extent and duration of their exposure to such changes. Another set of influential, interacting factors comprises the type and content of information provided by the media, industry, and governmental and non-governmental organizations with regard to global environmental change and its causes and effects.

The impacts of local, national, and international, social, economic, and political structures and institutions on the global environment include direct and indirect consequences, those that were

intended and foreseen as well as those that were neither sought nor anticipated. Many formal and informal structures and institutions - including education, markets, accounting systems, governmental policies, regulations, laws, and international agreements - shape and mediate human behavior that has consequences for the global environment. In turn, these formal and informal structures and institutions are shaped and affected by perceptions and assessments of environmental conditions and change as well as cultural and historical contexts.

Exploration of the human dimensions of global environmental change must include research both within these themes and on the interactions between them. All three themes include issues that are considered by several social sciences. Consequently, this research must involve collaboration among scientists from diverse disciplines. It must also be undertaken in a coherent way throughout the world, to assess how local societal conditions and the interactions of social, economic, and political processes in different parts of the world affect the ways human activities cause and are affected by global environmental change.

Global environmental change by definition concerns the world community as a whole. Moreover, the processes involved occur over long time periods, of decades to centuries. Thus, research on the human dimensions of global environmental change will require the spatial and temporal expansion of the conceptual, theoretical, and methodological frameworks of the social sciences. While these developments pose daunting challenges for the social sciences, the urgency of understanding and dealing with global environmental change demands that social scientists meet these challenges.

Part II of this document outlines the basic physical, chemical, and biological processes involved in global environmental change and the most important of the direct links between human activities and these processes. Part III first describes the broad emphases and aims of the proposed research, then introduces seven specific research topics and the conceptual and methodological issues that will have to be addressed in doing this research. Part IV sums up the challenge for the social sciences posed by the necessity of understanding the human dimensions of global environmental change.

II The earth system

Research on the human dimensions of global environmental change must take as its point of departure the interaction between human activities and the Earth's physical, chemical and biological systems. Consequently, a description of these systems and their processes is an essential prelude to the Framework for Research.

The total Earth system, from the center of the planet to the outer edges of its atmosphere, can be described in terms of a number of systems. The simplest classification consists of two systems: the geosphere and the biosphere. The geosphere includes the inanimate lithosphere (rocks), pedosphere (soils), hydrosphere (liquid water and ice), and atmosphere, which stretches from the troposphere (up to 10 km from the Earth's surface), to the stratosphere (10-50 km) and higher layers. The biosphere is "the integrated living and life-supporting system comprising the peripheral envelope of Planet Earth together with its surrounding atmosphere so far down, and up, as any form of life exists naturally" (Friedman, 1985: 20). Hence the two systems are interwoven within the oceans and bodies of fresh water, on land, and in the atmosphere. *Homo sapiens* is a living organism, whose activities take place within the biosphere. Yet, as discussed below, many of these activities also affect portions of the geosphere, contributing to global environmental change.

The components of the geosphere and biosphere are intricately linked by processes involving transfers of energy and matter. For the purposes of this document, the processes involved in the evolution of the solid Earth (lithosphere) will generally be ignored, since most operate on time-scales far longer than those relevant for research relating to human activities. However, there are exceptions, particularly processes of erosion and deposition, which affect land use patterns, and volcanic eruptions, which directly influence weather (and often land use patterns). At the time-scales relevant for research on human activities (up to hundreds of years), processes can be described within two broad systems: the biogeochemical cycles and the climate system. These are linked by both physical and chemical processes, involving particularly the formation and movement of water as vapor, liquid water, and ice.

The remainder of this section briefly describes: the biogeochemical cycles and the climate system; physical, chemical, and biological disturbances in these systems and the potential effects of these disturbances; and human activities that contribute to these processes, thereby causing global environmental change. As discussed previously, global environmental change includes both changes which take place throughout a global system and those which take place across the globe, but in discrete locations. As discussed below, these two types of change are directly linked through interactions of the biogeochemical cycles and the climate system.

A. Natural physical systems

1. Biogeochemical cycles

Biogeochemical cycles describe the movements and interactions, through the geosphere and biosphere, of the chemicals essential to life. These cycles involve a range of physical, chemical, and biological processes. Foremost among the essential chemicals are the elements of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur, combined in various forms and also interacting with other elements. The cycles of these elements significantly influence atmospheric and oceanic chemistry and the global energy balance.

Biogeochemical cycles in the hydrosphere, atmosphere, and terrestrial environment are intricately linked and are closed at the global scale. The cycling processes for individual elements and compounds vary considerably both between and in these systems, especially in terms of rates. Only recently have the dynamics of the cycling of individual elements and compounds and, in particular, the scale and role of the contribution of human activities to these processes, begun to be understood at a global scale; this field of research is experiencing rapid evolution (McElroy and Moore, 1988).

2. Climate system

The principal source of change in the climate system is solar radiation, whose input to the Earth system varies with latitude, season, and time of day. Losses of energy from the Earth system are also critical as a source of change in the climate system. These losses are controlled by a number of factors, including the distribution and nature of land and water surfaces and clouds, and the chemi-

cal composition of the atmosphere. The thermal imbalances between high and low latitudes result in the global circulation of the atmosphere, i.e., wind systems that redistribute energy and matter throughout the atmosphere. This atmospheric circulation also applies stresses to the upper layers of the oceans, influencing ocean currents which in turn redistribute energy and matter, albeit at longer time-scales than in the atmosphere. The evaporation and precipitation of water are critical processes linking these two types of circulation.

Understanding of the processes of the climate system is increasing, primarily through the use of large computer models. In particular, these models help to resolve issues of non-linearity in the climate system and of uncertainty with respect to interactions between its components (e.g., clouds, oceans, and vegetation). However, considerable research is still required in the fields of both data collection and the incorporation of critical processes in these models, which can still not be used in predictive mode, especially at the regional scale (Earth System Sciences Committee, 1986; Dickinson, 1988).

B. Disturbances in natural physical systems and their potential effects

1. Climate change

a. Processes involved

As described above, the climate system continually changes as a result of interactions between solar radiation and the components of the geosphere and biosphere (Dickinson, 1986). While these changes have been occurring for billions of years, a significant new factor has been introduced in the recent past: the emission of "greenhouse gases" as a result of the activities of human populations. These gases keep the lower atmosphere and Earth's surface warm by absorbing infrared radiation emitted by the Earth's surface and reradiating this energy (Ramanathan et al., 1985). Most greenhouse gases are not a new component of the atmosphere; if they were not in the atmosphere, there would be no "greenhouse effect," and life on Earth would not be possible because the global average temperature would be about 30C cooler: below the freezing point of water.

The primary greenhouse gas is water vapor, which accounts for about 80% of the greenhouse effect. The rest of the effect is due to

gases at very low concentrations, i.e., trace gases. Anthropogenic climate change relates primarily to an enhanced greenhouse effect resulting from increases in the concentrations of these gases, especially carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tropospheric ozone (O_3), and the chlorofluorocarbons (CFCs) (Jaeger and Barry, 1989). All but the last of these gases occur naturally in the atmosphere and are removed naturally to the geosphere and biosphere through biogeochemical cycling. However, as a result of the human activities discussed below under "human systems", and the long lifetimes of molecules of these gases in the atmosphere (5-400 years), their concentrations have increased to levels which are higher than these processes can remove at time scales shorter than those of geological time.

The data showing the increasing atmospheric concentrations of greenhouse trace gases are conclusive (Bolin et al., 1986). Samples of air taken from bubbles in antarctic ice, which record concentrations as far back as 160,000 years ago, show increases from about two centuries ago, coincident with the beginning of the industrial revolution. Measurements of the chemical composition of air, taken at locations far from centers of human settlement and industrial activity, show rises in the concentration of these gases over more than 30 years.

b. Potential effects

With a knowledge of both the principal processes driving the climate system and the rates of change in the concentration of greenhouse trace gases, atmospheric scientists have constructed models to investigate possible changes in the climate system resulting from the emission of these gases. Results from these models have led to consensus that 1) the past emission of these gases has enhanced, and continues to enhance, the greenhouse effect, causing the global average temperature to increase, and 2) that continued emissions will cause a rise in global mean temperature that is larger and more rapid than any experienced in human history (Jaeger, 1988). Temperature records suggest that global mean temperature has increased over the past century, providing rough validation of the results of these models (Schneider, 1989).

At present, global climate models cannot be used to predict the probable distribution of changes in the climate system in either space or, especially, time. With regard to the likely spatial distribu-

tion of changes, there is some agreement on temperature, but little on precipitation. Equally, while the models can suggest possible gross changes in atmospheric circulation patterns, they cannot be used to predict changes in the variability of climatic variables or the location or frequency of extreme events (e.g., droughts, hurricanes, storm surges). The only reasonably certain predictions that can be made are that global sea level will rise as a result of thermal expansion of the oceans, and that changes will be at different rates (and even directions) in different places (Jaeger, 1988). These changes may be ameliorated or exacerbated at regional and local scales by other human activities (e.g., deforestation, irrigation, desertification) which change the characteristics of the land surface (Jaeger and Barry, 1989). An additional serious concern is that many ecosystems and species may not be able to adapt to rapid rates of change in climate variables (Wilson, 1989).

2. Stratospheric ozone depletion

a. Processes involved

Ozone is found throughout the atmosphere, with its highest concentrations in the "ozone layer" of the stratosphere, where it is formed when solar ultraviolet (UV) radiation breaks down molecules of oxygen (O_2) to produce two oxygen atoms (O) which combine with other oxygen molecules to form ozone (O_3) molecules. These molecules are in turn broken apart by UV radiation, maintaining a balance between O, O_2, and O_3 in the stratosphere. Stratospheric ozone depletion is a process that occurs when this balance is upset as a result of reactions between ozone molecules and chlorine, nitrogen, bromine, either as atoms or combined with other elements, thus reducing overall ozone concentrations (Cicerone, 1987).

Chlorine, nitrogen, and bromine all occur naturally in the stratosphere. However, the concentration of chlorine and bromine atoms, in particular, has increased greatly in the past three decades as the result of increasing emissions of halocarbons, as discussed below under "human systems." These chemicals are very stable in the troposphere and pass upwards into the stratosphere, where they are broken down by UV radiation. Once chlorine and bromine atoms have been released by this process, they begin the catalytic process of ozone depletion. As each atom has a lifetime of about 100 years, it can destroy up to 10,000 ozone molecules (Miller and Mintzer, 1986). To some extent, stratospheric ozone

depletion may be moderated by increased concentrations of other greenhouse trace gases (CO_2, CH_4, N_2O) in the stratosphere (Mahlman, 1989).

b. Potential effects

The processes of stratospheric ozone depletion have caused a marked reduction in average global ozone concentrations over the past two decades (Watson et al., 1988). These reductions vary seasonally and generally increase poleward. The most marked decreases have occurred during the Antarctic spring: concentrations measured in October 1987 were less than half those recorded in October 1979. These extreme events have become known as the formation of the "ozone hole," which results from a complex interaction of chemical and physical processes which do not occur at other latitudes (Watson, 1989). Atmospheric models show that stratospheric ozone concentrations will continue to decrease worldwide because of the long lifetimes of chlorine and bromine molecules already in the atmosphere and those that will be released in the future (Albritton, 1989). However, because neither the interactions between various chemicals in the stratosphere nor future emission rates are fully known, it is not possible to predict future rates of ozone depletion.

Stratospheric ozone is important for the biosphere because it absorbs much of the UV radiation which is harmful to animals and plants. As increased amounts of UV radiation reach the Earth's surface, human populations may be directly affected by increases in skin cancers, eye disorders, and immune system suppression. In addition, yields of some crops may decline, and changes in marine ecosystems may occur (WRI/IIED/UNEP, 1988). The process of UV absorption is also critical for climatic processes, in transforming solar radiation into the mechanical energy of winds and heat and initiating key chemical reactions (Cicerone, 1987). Consequently, stratospheric ozone depletion is likely to affect climate, further complicating the ability of scientists to predict future climate at either global or regional scales.

3. Acid deposition

a. Processes involved

Acid deposition refers to the deposition onto components of the biosphere (including vegetation, water bodies, and the infrastructure of human societies) of chemicals which, when dissolved in water, increase its acidity. The most common of these chemicals are nitrogen oxides (NO_x) and sulfur dioxide (SO_2). A very small proportion of these chemicals derives from natural sources. However, the primary sources result from the combustion of both fossil fuels, especially during the generation of electricity from coal, and biomass fuels. These chemicals are transformed in the atmosphere by a complex series of catalytic and photochemically-initiated reactions. After a period of hours to weeks, during which time they generally travel a few tens to a few hundred km, the chemicals are precipitated from the atmosphere in wet deposition (rain, fog, dew, snow, hail), or as dry gases or particles (National Research Council, 1986).

b. Potential effects

Acid deposition affects both the aquatic and terrestrial components of the biosphere. The spatial distribution of these effects is closely linked to the location of combustion of biomass and, especially, fossil fuels and the course of air masses into which the acidifying chemicals are released. Given the relatively short lifetime of these chemicals and the scattered distribution and varying intensity of their primary sources, there is debate as to whether acid deposition is a global, rather than local or regional, environmental problem. However, as industrialization proceeds, acid deposition is likely to increase its spatial scale (Graedel and Crutzen, 1989).

Acid deposition has considerable effects on aquatic ecosystems, initially by increasing the acidity of streams, rivers, and lakes. The susceptibility of these water bodies to acidification depends primarily on the geology and soils of their watersheds, but also on patterns of precipitation and water supply. As acidity increases, increasing numbers of fish and other organisms are killed or become unable to reproduce. Terrestrial vegetation is also affected by acid deposition. However, the processes by which this occurs are complex, generally involve other chemical and physical processes, and remain unclear. Sulfur dioxide is known to damage and kill all types of plants when released at high concentrations. Acid deposition has been cited as a cause of slow growth, often ending in "forest dieback," in both coniferous and deciduous trees, as a result of changes in both soils and vegetation. Detrimental effects of acid deposition on crops may occur, but have not been clearly demonstrated (Hendrey, 1986). Finally, acid deposition can substantially

damage both societal infrastructure, including buildings, transportation networks, and water supplies, and cultural and historical structures and artifacts (Schneider, 1986).

4. Loss of biodiversity

a. Concepts and processes

Biodiversity describes the variety of the living components of the biosphere, the result of the processes of evolution of both assemblages of species (ecosystems) and individual species. Biodiversity may be described at three levels. Ecosystem diversity describes the range of ecosystems in a given area, up to the scale of the Earth. Species diversity describes the range of species in a given area, from a single ecosystem to the Earth. It is estimated that between 5 and 30 million species exist on the Earth (Wilson, 1988). Genetic diversity describes genetic information, at scales from a single organism to the Earth. A single organism may have from about 1,000 genes (bacteria) to over 400,000 (many flowering plants and some animals) (Hinegardner, 1976).

Loss of biodiversity is the process whereby ecosystems, species, and genes become extinct. This takes place as a result of natural occurrences, but has been accelerated in the recent past by human activities. One example occurs when new organisms are introduced to islands (or even continents) where they outcompete indigenous organisms, which consequently are greatly reduced in number or die out, often causing irreversible changes in ecosystems (Crosby, 1986).

At present, the greatest loss of species and genetic diversity is taking place as a result of land use change and deforestation in tropical rain forests, which contain over half the Earth's species. Rates of extinction may be 1,000 to 10,000 times greater than before human intervention. Other species-rich ecosystems, especially tropical coral reefs, geologically ancient lakes, and coastal wetlands, are also highly susceptible to loss of diversity through similar human activities. In all of these ecosystems, loss of biodiversity results from the destruction of individuals (up to the level of entire species), and changes in (up to the destruction of) physical and biological environments required for the continuation of species. One critical factor is the size of ecosystem left after land use change; this directly affects the number of species able to survive in an area (Wilson, 1988).

b. Potential effects

Loss of biodiversity may have a wide range of potential effects on both natural and managed ecosystems and the human populations which depend on them. Only a few of these effects can be presented below. At the level of species diversity, the loss of one insect species may lead to the failure of crops which depend on it for pollination, while the loss of another may lead to outbreaks of pests which it controls. The extinction of subterranean organisms may destroy soil fertility. The loss of one species in a food chain may lead to the decline or extinction of others at higher levels (Ehrlich, 1988). All of these examples can have direct effects on the ability of human populations to survive.

All losses of species diversity inevitably decrease genetic diversity. From the point of view of human populations, this is critical since it represents the loss of unique genetic information. Such information may be critical in breeding and developing organisms necessary for adapting to the effects of climate change and soil erosion, losses in pollinators, and increases in pest infestations (Ehrlich, 1988). In addition, the availability of genetic information can be vital for advances in human health and nutrition, agriculture, and forestry (Wilson, 1989).

C. Human systems

The activities of one species in the biosphere - *Homo sapiens* - now significantly affect many of the systems of the biosphere and the geosphere. Human beings may now be the primary agent of change in the lithosphere, at least in terms of material moved and transformed each year (Fyfe, 1981; Bender, 1986). Other human activities may also be reaching a magnitude where their influence on other systems is equivalent to the operation of natural processes, although this is not accepted without question (e.g., Smil, 1987).

There are a number of driving forces behind humankind's role as an agent of biospheric and geospheric change. These forces, which all interact, include the distribution and rates of growth of human populations and economies, and variations in human attitudes to economic growth and resource management, especially in terms of time horizons. To understand present and possible future

patterns of human activities, all of these forces must be understood in historical, current, and possible future contexts. The remainder of this section focuses on a number of significant human activities which derive in various ways from these driving forces, and both affect and are (or will be) affected by the processes disturbing physical systems which were described in the previous section.

1. Fossil fuel consumption

Since the early 19th century, fossil fuels have played an increasingly important role in the world economy, providing energy for industrial development, transportation, cooking, heating, cooling, and lighting. Since 1950, global energy demand has quadrupled, and per capita energy consumption has doubled. Global energy use patterns have also changed since 1950, when OECD countries consumed 75%, centrally-planned economies 19%, and developing countries 6%; by 1985, the relative proportions were 53%, 32%, and 15%. The relative proportions of energy used in different economic sectors also vary considerably, especially in relation to the degree of economic development (Braatz and Ebert, 1989). Patterns and sectoral distributions of energy use will continue to change as a result of population growth and economic development, with OECD countries accounting for a decreasing share of the total.

Fossil fuels now provide about 85% of the world's energy requirements. However, this dependence varies between countries; fossil fuels provide over 95% of energy needs in industrialized countries, but only 55% in developing countries, where biomass is an important, and sometimes dominant, fuel source (Hall et al., 1982). Again, these patterns are likely to change in the future as a result of economic and technological developments.

The burning of fossil fuels produces significant volumes of CO_2, and some CH_4 and N_20. Thus, fossil fuel consumption is the foremost cause of anthropogenic climate change. Ratios of greenhouse gas to energy production vary considerably between types of fuel and technology. For instance, to provide the same energy output, coal produces relatively more CO_2 than oil, which in turn produces relatively more than natural gas. Greenhouse gases, especially CH_4, are also released in the extraction, processing, and transportation of fossil fuels (Braatz and Ebert, 1989). Fossil fuel combustion is also the primary cause of acid deposition, with coal

accounting for the release of far more SO_2 and NO_x (per unit of energy derived) than oil; emissions of these chemicals from natural gas are negligible (Husar, 1986). Future trends of the contribution of fossil fuel combustion to climate change and acid deposition depend on unknown developments in the growth of population and economies, technological developments and transfers, energy prices, and many other factors. Consequently, it is very difficult to forecast these trends.

2. Biomass fuel consumption

Biomass fuel consumption refers to the use of wood, animal dung, and agricultural waste products for fuel for industrial, commercial, and domestic purposes. While biomass fuels provide only 14% of global energy use, they are the primary energy source for over 2 billion people, accounting for 63% of total energy use in African, 17% in Asian, and 16% in Latin American developing countries (Lashof and Tirpak, 1989). Two out of three developing countries suffer severe fuelwood shortages; half of these have no proven oil or gas reserves. Since national incomes and economic growth rates are also low, possibilities for switching to fossil fuel consumption are highly limited (FAO, 1987).

Energy production from biomass fuel consumption is typically very inefficient because of the poor design of stoves, heaters, kilns, boilers and other devices. There is considerable potential for developing and introducing new technologies to improve energy efficiency, although this requires clear understanding of specific economic and cultural situations. One important area of technological change may relate to the production, from dung, of "biogas" for fuel. At present, inefficient use of dung for fuel means that not only is energy wasted, but an important source of nutrients is lost from agriculture; in contrast, residues from biogas generation can be used for fertilizer. Thus, negative feedbacks to human health and economic development could be decreased.

The consumption of biomass fuels is closely linked to major processes of global environmental change, in ways that are exacerbated by the low efficiency of energy production. The combustion of these fuels results in the emission of CO_2, CH_4, and N_2O, contributing to global climate change, and some SO_2 and NO_x, possibly contributing to acid deposition especially around cities in developing countries. At local and regional levels, the removal of

plant cover alters land surface properties, potentially changing climates at these scales. Also, the extraction of biomass fuels can affect biodiversity, especially in tropical countries with diverse ecosystems.

3. Land use change

Land use change includes:

- the conversion of forests to crop- and rangeland, the intentional and inadvertent burning of forests, and the removal of wood for fuel (deforestation);

- losses of productive crop- and rangeland through overgrazing, drought and other factors, involving the interaction of human activities and natural processes (desertification and salinization);

- the conversion of wetlands to agricultural and urban uses;

- the conversion of other types of land to uses associated with the growth of human populations (urbanization, development of infrastructures for transportation, energy production, and water storage, etc.). All of these processes cause changes in biogeochemical cycles, in biodiversity, and in the climate system, at scales from the local (through changes in land use characteristics) to the global (through the emission of greenhouse gases).

At the global scale, deforestation has been, and is, an important contributor to climate change, since CO_2, CH_4, and N_2O are released by both burning and soil disturbance associated with logging and land clearance. Since 1850, the global area of forest and woodland has decreased 15%, primarily in Africa, Asia, and Latin America. In Europe and North America, forest cover has changed little in this period. While the current annual rate of tropical deforestation is estimated at c. 11 million ha, there is considerable disagreement between estimates, and also in definitions of deforestation, since an area can remain "forest" even when the density of trees has decreased (WRI/IIED, 1987; WRI/IIED/UNEP, 1988).

4. Agricultural activities

Apart from the considerable use of fossil and biomass fuels in food production, distribution, and preparation and the conversion of other types of land use to agricultural purposes, a number of agricultural activities, all linked to growing human populations and

economic development, are important as a causal factor in climate change. These activities include biomass burning (of agricultural wastes and in shifting agriculture, with results similar to deforestation), rice cultivation, livestock management, and the use of nitrogenous fertilizers.

The area under rice cultivation increased 40% from 1950 to 1984; over 90% of the global acreage is in Asia. Rice cultivation is primarily linked to climate change through the release of CH_4 due to the anaerobic decomposition of fertilizer and crop residues in paddy fields. The global contribution of this source of CH_4 is uncertain; it may be decreased by adoption of new varieties of rice and farming practices (Burke, 1989).

Livestock, especially cattle, release significant volumes of CH_4 to the atmosphere as a by-product of digestion. The global livestock population has increased considerably over the past century, though at lower rates since the 1960s. Livestock both provide food and supply fertilizer and power for agriculture; draft animals remain the dominant source of agricultural power in most developing countries. Possibilities for significantly reducing emission rates, without major changes in dietary habits or substituting fossil-fuel-burning technologies for draft power, are probably limited (Braatz and Ebert, 1989).

Nitrogenous fertilizers have been important in increasing crop yields over the past few decades. These chemicals all release N_2O to the atmosphere as a result of microbial action in the soil. Estimates of the consequent contribution to climate change are highly uncertain because of the complexity of the processes leading to N_2O release. At present, the principal users of nitrogenous fertilizers, in terms of volume, are China, the USSR, and the USA. However, the types that tend to release the most N_2O are mainly used in industrialized countries. Conversely, the types that release the least N_2O tend to predominate in developing countries (Fung et al., 1988). Possibilities for decreasing emission rates primarily relate to using different types of fertilizer and changing application techniques and other agricultural practices. In many cases, these changes may improve agricultural productivity (Burke, 1989).

5. Halocarbon production and release

Halocarbons include two major groups of chemicals: chlorofluorocarbons (CFCs) and halons. These chemicals are significant in the

disturbance of the climate system because they are both very effective greenhouse gases (per molecule, some absorb up to 30,000 times more IR radiation than CO_2) and provide catalysts for stratospheric ozone depletion. CFCs are man-made chemicals produced commercially since 1931. In the troposphere, they are inert, nonflammable, and highly stable. Initially, these characteristics made them valuable as coolants; they have subsequently been used as propellants in aerosols and foam manufacture, and as solvents. Halons have been used in fire extinguishers since the 1970s (Lashof and Tirpak, 1989).

Production of both CFCs and halons has grown steadily as new uses have been found, especially in the 1960s and 1970s. While most halocarbon production and consumption occurs in industrialized countries, consumption is also growing in developing countries. Total production of CFCs peaked in 1974, with a subsequent decline because of bans on their use in aerosols in the USA, Canada, and some European countries (WRI/IIED/UNEP, 1988). While production has been increasing in recent years, rates of production are likely to slow as a result of the "Montreal Protocol on Substances that Deplete the Ozone Layer," signed in 1987 (Morrisette, 1989) and subsequently ratified and strengthened by the countries accounting for the majority of production and consumption.

In spite of these developments, considerable volumes of halocarbons will continue to be released to, and present in, the atmosphere for centuries, for three reasons: 1) continued halocarbon manufacture and use; 2) the volume of halocarbons already manufactured and present in cooling systems, foams, and fire extinguishers; and 3) the long lifetimes of these molecules (20-400 years). Thus, even if the Montreal Protocol is fully implemented, atmospheric concentrations will increase in future decades.

III A FRAMEWORK FOR RESEARCH

Our framework for research is divided into four main sections. The first presents the emphases of the program. The second highlights the aims of the research suggested within the framework. The third outlines seven research topics central to understanding the human dimensions of global environmental change, while the final section discusses conceptual and methodological developments required for the study of the human dimensions of global environmental change. These conceptual and methodological developments must be given high priority.

A. Emphases of research

Research on the human dimensions of global environmental change should complement and, when appropriate, interact with natural science research on changes in the Earth's physical, chemical, and biological systems. Much of the research that needs to be undertaken in relation to the human dimensions of global environmental change has been, and will continue to be, done by individuals and groups within and across disciplines, typically at the local, sub-national, or national level. ISSC cannot be directly involved in such research, but should encourage its development, especially through the activities of the council's member unions, and should facilitate the dissemination of the results of this research.

ISSC itself will promote research through the periodic development of work programs that encompass activities with clearly-defined goals and time-frames. Research conducted through these work programs should have two primary emphases. First, ISSC should foster interdisciplinary research, with participation both among social science disciplines and between natural and social science disciplines. The breadth of disciplinary involvement must be closely tailored to the objectives of each project. Second, ISSC should foster research that needs to be undertaken in parallel, cooperatively, or internationally. Parallel work involves individuals who are doing research maintaining sufficient contact so that they can follow parallel procedures that will ensure that their findings are comparable. In cooperative work, independent investigators

execute a commonly agreed research design in different locales, using standardized methodologies that ensure that results are comparable. International work is done by teams that are composed on an international basis and generally has an international or global focus. ISSC has a special mission to promote cooperative and international research and to encourage mechanisms that facilitate parallel work.

For both interdisciplinary and international research projects to proceed successfully, efficient communication and clear understanding must be explicitly developed between individuals in all involved disciplines. This must occur at all stages of research, from objective-setting, through choice of methodologies and conceptual frameworks, to analysis, interpretation, and dissemination of results.

In addition to the two primary emphases described above, research projects fostered by ISSC should have an important secondary emphasis: to contribute to the professional growth of scientists from countries - especially developing countries - without strong traditions in the social sciences or interdisciplinary science. Research on the human dimensions of global environmental change must be planned and conducted globally. This can only occur if there are strong communities of social scientists doing this research throughout the world.

B. Aims of research

As outlined in Part II on "The Earth System," global environmental changes are inextricably linked to human activities. For the purpose of designing research strategies, it is necessary to categorize these links into processes operating in two directions; although it must be recognized that there are innumerable feedbacks between these directions. The primary aim of research fostered by ISSC should be to increase understanding of the processes relating to human activities which take place in these two directions - and, as far as possible, the feedbacks and links between these processes - in order to contribute to informed long-term sustainable use of the Earth's systems.

The first direction concerns *the contribution of human activities to change*, as described under "human systems." In this direction, it is critical to note that many human activities are causally linked to a number of types of change in different Earth systems. Hence the relationships between each activity and all possible resultant changes should be considered in at least the first phase of research. The second direction concerns *what individuals, societies, and local, national, and international institutions have done and could and might do in the face of ongoing and anticipated change.* These responses include a wide variety of behavioral, social, economic, political, legal, and other processes at all levels. They might involve efforts to cope with or change adapt to change, or efforts to ameliorate and even arrest change. Since all physical Earth systems are linked through biogeochemical cycles and the climate system, and because all human systems are interconnected to some extent, these potential responses will have a wide range of possible effects. These in turn may require additional responses by individuals, societies, and local, national, and international institutions, necessitating further analysis of options and effects.

C. Research topics

ISSC must foster research on topics that are truly central to understanding the human dimensions of global environmental change. The human activities that interact with the Earth's natural systems are driven by three fundamental factors: the number of human beings and their distribution around the globe; their needs and desires - as conditioned by psychological, cultural, economic, and historical factors - which provide their motivations to act; and the cultural, social, economic, and political structures and institutions and norms and laws that shape and mediate their behavior.

These factors can be encompassed within three broadly defined research topics: the social dimensions of resource use; the perception and assessment of global environmental conditions and change; and the impacts of local, national and international social, economic, and political structures and institutions on the global environment. Each of these topics must be investigated separately. In addition, they must be investigated in combination as they interact in specifically defined contexts where human activities have a direct impact on the physical, chemical, and biological processes that are involved in global environmental change. Such research

must be conducted at all geographical scales and should include the past as well as the present and the future.

The following seven topics have been chosen:

1. Social dimensions of resource use;
2. Perception and assessment of global environmental conditions and change;
3. Impacts of local, national, and international social, economic, and political structures and institutions;
4. Land use;
5. Energy production and consumption;
6. Industrial growth;
7. Environmental security and sustainable development.

Although these topics are listed according to an intellectual logic, their order implies neither the temporal sequence in which they should be undertaken, nor their priority.

The first, second, and third topics - namely: social dimensions of resource use; the perception and assessment of global environmental conditions and changes; and the impacts of local, national, and international social, economic, and political institutions, structures, and culture on the global environment - are those that have been broadly identified as central to understanding the human dimensions of global environmental change.

1. Social Dimensions of Resource Use

Research on the dynamics of interactions between population and resources, and constraints on these, must consider both demographic characteristics and variations in them, and interactions of populations, economic and urban growth, technology, and resource use. Demographic changes, both structural and locational, are a driving force in global environmental change. The size of the world's population, its distribution, cultural models of consumption, and transfers of capital and resources between countries affect economic, social, and technological changes and are, in turn, affected by them. These interactive processes affect the use of land, water, air, and renewable and non-renewable resources.

Great progress has been made in understanding the dynamics of population growth, internal and international migration, and urbanization. Populations throughout the world are also characterized by significant changes in the structure and families and workforces, age distribution, and rates of fertility. These trends have considerable potential for causing global environmental change, and for being affected by it, and thus provide critical areas for research.

Many factors conducive to and promoting economic growth have been identified. There is growing knowledge about the factors that contribute to and limit technological innovation. Projections of resource use are commonplace, usually linked to assumptions about population and economic growth. These projections provide a starting point for the work that needs to be done, yet they need to become more comprehensive, through the inclusion of additional variables and feedback effects, many of which are not easily (if at all) quantifiable. This requires the participation of social scientists from a wider range of disciplines than have previously been involved.

Resource and development economists, demographers, geographers, and systems analysts need to refine their models with insights from other social scientists. Then they need to work together to combine their refined models to provide better projections of the dynamics of resource use.

2. Perception and assessment of global environmental conditions and change

The perception and assessment of global environmental conditions and changes by governmental policy makers, managers of industrial enterprises, and societal groups of all sizes affect how they react to and behave toward these conditions and changes. Individuals' assessments and perceptions of global environmental change are largely subjective and probabilistic, and will be affected by many interacting factors, including their individual attributes; their cultural background; their social, economic, and political setting; and the extent and duration of their exposure to such changes. For these reasons alone, there will seldom be direct correlations between physical conditions and human perceptions of these conditions. These perceptions, and the many potential behavioral responses to them, will be further modified by the type and content

of information provided by the media, industry, and governmental and non-governmental organizations with regard to global environmental change and its causes and measured and hypothetical effects at different spatial scales.

Random and stratified sample surveys are well-developed methodologies of social science research. Through surveys and controlled experiments, much is known about attitude formation and about relationships between attitudes and behavior. Cognitive science has made great advances which have been integrated in studies of risk assessment. Research in these broad areas provides much baseline data. However, most of the data and much of the knowledge concerns general publics within developed countries. The knowledge includes a basic understanding of the interaction between media and attitudes. In contrast, knowledge of environmental perception and assessment in developing countries is generally scattered, and largely based on case studies from specific study locations. At the same time, great care must be taken in the interpretation of aggregate data. There is often considerable variation in perceptions, and resultant behavioral responses, both within and among nation states.

While there have been surveys and case studies of attitudes toward environmental conditions, some at the multinational level, few of these have focussed specifically on issues related to global environmental change. There are no baseline data on public attitudes worldwide toward global environmental conditions and changes in these conditions. Nor are there baseline data concerning the relationships between individual and collective behavior and global environmental change. It is crucially important that those studies that have focussed specifically on aspects of global environmental change should be compiled, so that they can be used as a foundation for worldwide baseline surveys. It is also important that the many studies of attitudes towards general environmental conditions be compiled, so that steps can be taken analyses of relationships between attitudes concerning local and global environmental issues can be undertaken.

Broad theories about attitude formation and relationships between attitudes and behavior should be applied in the context of global environmental issues. However, this will require the collection of data, using both case study and survey techniques, concerning attitudes toward global environmental conditions and change. Finally, relationships among the attitudes of the general public,

leaders of public and private groups, and governmental officials must be investigated and understood. A critical issue is the discovery and evolution of new environmental issues of all scales; comparative case studies in this area will be of great value for theoretical and methodological development in the social sciences.

3. Impacts of local, national and international social, economic and political structures and institutions.

The impacts of local, national and international social, economic and political structures and institutions include direct and indirect consequences, those that were intended and foreseen as well as those that were neither sought nor anticipated. Many formal and informal structures and institutions, including education, markets, accounting systems, governmental policies, regulations, laws, and international agreements shape and mediate human behavior that has consequences for the global environment. In turn, these formal and informal structures and institutions are shaped and affected by perceptions and assessments of environmental conditions and change as well as cultural and historical contexts.

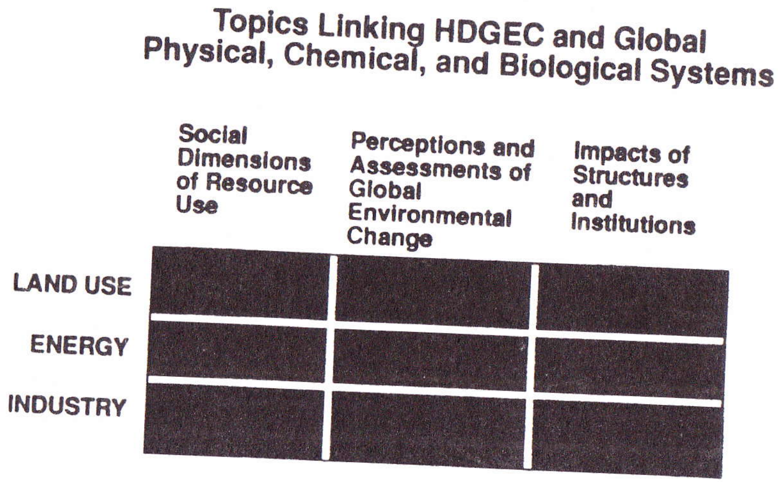
Local, national, and international social, economic, and political structures and institutions have generally been studied in isolation from one another, and the focus has usually been on their primary and intended effects on such goals as promoting economic growth, economic and social equity, national security, public health and, less frequently, environmental quality. These studies are rich sources of data and theoretical insights. They provide a strong foundation for the essential work that will consider the combined direct and indirect, intended and unintended impacts of structures and institutions on global physical, chemical, and biological systems. Such holistic studies are necessary for three reasons. First, actions undertaken at a single locale are having effects at increasing spatial scales. Second, actions undertaken in one sphere or locale can be negated, or even exacerbated, by other actions elsewhere. Finally, efforts to deal with one issue may have harmful and unexpected side-effects.

One limitation of existing theories and methodologies relating to structures and institutions is that they primarily consider nation states in the industrialized world. The influence of cultural and societal norms and values on environmental conditions has, conversely, been largely examined through local case studies in developing

countries. Thus, a major challenge of research on interactions between human behaviors and environmental conditions at all scales will be to integrate these two very different conceptual and methodological approaches. Further challenges will be to evolve concepts and methodologies appropriate to global-scale research and to conceive new forms of institutions and structures such as accounting systems for measuring economic activities, non-governmental organizations, and international agreements that could efficiently and effectively address issues posed by global environmental change. All of these challenges will require substantial interdisciplinary cooperation.

The first, second, and third topics need to be explored in broad, general terms. They also need to be explored in the context of specific issues of critical relevance to the interaction between human activities and global physical, chemical, and biological systems. The three most salient issues are land use, energy production and consumption, and industrial growth. These issues constitute the fourth, fifth, and sixth topics in this Framework for Research. Research on these topics must in each case involve investigation of the social dimensions of resource use involved in the issue, the perception and assessment of the conditions of and changes in relevant parts of the global environment, and the impacts of local, national, and international structures and institutions on the issue. Figure 2 illustrates this interaction.

FIGURE 2:



This research will build on, and contribute to, work concerning the first, second, and third topics. It will establish links among them and between them and ongoing research in the natural sciences.

4. Land use

Land use is a critical topic in global environmental change, and has been identified as a priority issue in many ongoing national and international research initiatives. Patterns of land use both determine and are determined by essential human activities, such as the production of food and fuel and the development of settlement and transportation patterns. Changes in patterns of land use, whether caused by physical, biological, or societal processes, can have strong influences on the processes of climate change and loss of biodiversity. In turn, land use will be affected by both these processes and acid deposition, and possibly by stratospheric ozone depletion. In general terms, changes in land use can be subsumed under three main themes: urbanization (and other changes in settlement and transportation patterns); agriculture; and forestry (including both natural and managed ecosystems).

5. Energy production and consumption

The production and consumption of energy are issues that concern all countries and individuals. Energy is vital for sustaining life and for all economic activities. Yet the extraction of fossil and biomass fuels contributes to climate change and loss of biodiversity, and the combustion of these fuels is the primary agent of both anthropogenic climate change and acid deposition. In turn, climate change is likely to affect future demands for energy which may, in the future, be increasingly supplied by alternative sources with fewer overall deleterious effects to the Earth's systems. The introduction of these sources may substantially affect patterns of human settlement, land use, and economic development.

6. Industrial growth

Industrial growth is closely tied to patterns of energy use. It also depends on many other factors, such as the availability of non-energy resources and the technologies for their utilization and recycling, demands for industrial products, and available technologies

for their production. In turn, these factors are linked to the decisions of public and private institutions and to societal values, perceptions, and levels of economic development. Industrial processes contribute to global environmental change not only through the emission of gases resulting from energy consumption, but also in many other ways, such as releases of CFCs and other gases, heavy metals, and particulates.

The final topic involves primarily the human response to global environmental change. What can governments and populations do to cope with, adapt to, or seek to ameliorate or even arrest the processes of global environmental change? This question cannot be answered in the abstract, but must be put in the context of diverse human goals. The adoption of measures to protect the Earth's physical, chemical, and biological systems that would involve foregoing all future economic growth is inconceivable. Nevertheless, the apparent risk to the Earth's habitability demands that steps be taken to promote environmental security and sustainable development. Thus these are the final topics in this Framework for Research.

7. Environmental security and sustainable development

Environmental Security should be considered as an essential component of a comprehensive concept of human security along with economic, humanitarian, and social, as well as political and military security. From this perspective, environmental security raises unprecedented issues concerning the organization of society and the norms that should guide individual and collective behavior. In particular, consideration of environmental security leads to questions about the interpretation of the concept of sovereignty, the fundamental principle on which the human global system is based, in an era of global environmental change. How free should and could states be to take actions which may have harmful environmental effects beyond their borders or for future generations?

Research on environmental security should analyze the prospective costs and benefits of various relevant individual, local, national, and international courses of action in an unpredictable world. These costs and benefits may be felt in social, cultural, economic, political, and environmental spheres. Issues involved in inter-personal, inter-regional, international, and inter-generational conflicts of interest must be explored. More attention should be

given to how common resources such as the atmosphere, the oceans, Antarctica, and genetic diversity have been treated and might be protected. The great potential range of costs and benefits, many of which may be unquantifiable in monetary terms, will necessitate considerable evolution in the methodology of existing fields of social science, including the development of new concepts for inclusion in systems of economic accounting, and likely the creation of new interdisciplinary fields or emphases within disciplines, in order to consider these issues.

Historical research is also appropriate in regard to environmental security. Such research may be used to gain increased understanding of the ways in which humankind has in the past conquered common problems to see if there are insights that may be helpful in dealing with global environmental change.

The concept of sustainable development, as defined in the report of the UN World Commission on Environment and Development (1987), *Our Common Future*, has won wide acceptance as the goal for the management of global environmental change. Yet its meaning is not well understood. Definitions abound. They primarily consider the ecological and economic dimensions of the concept, generally slighting its social, cultural, and political aspects. They frequently are based on notions of attaining equilibrium states, when evolutionary concepts may be more appropriate, especially under the current trends of accelerating and cumulative global environmental change. Given the prominence of the concept of sustainable development in discourse about global environmental change, the concept clearly needs to be jointly explored by social and natural scientists from several disciplines and all areas of the world. This exploration is also essential to analysis of environmental security.

D. Conceptual and methodological issues in the study of the human dimensions of global environmental change

Because of its critical importance for successful research on the human dimensions of global environmental change, a major objective of this Framework for Research is to stimulate research that will contribute to the conceptual, theoretical, and methodological development of the social sciences, both within disciplines and through the expansion of existing interdisciplinary fields of enquiry

and the creation of new ones. As discussed in Part II on the Earth System, a wide and increasing range of human activities across the globe contribute to change in the Earth's physical, chemical, and biological systems. While many of the techniques of the natural sciences, such as remote sensing, can provide information concerning these systems at a global scale and have led to an expansion of these sciences to include the study of global phenomena, often in interdisciplinary contexts, such methodological and spatial evolution has generally not taken place in the social sciences.

New observation techniques, such as those of remote sensing, have not yet been used extensively to study such processes as flows of human beings and the production and movement of goods. All of these processes are increasingly taking place at a global scale. Furthermore, most methodologies for research in the social sciences have evolved for use at national or smaller scales, and the nation state, rather than the globe provides a fundamental organizing framework frequently utilized for research in social sciences. Also, communication between different social sciences - and even within individual social sciences - is often limited by a lack of shared concepts, terms, information, and comparable or compatible time- and spatial-scales. Only a few social scientists have experience doing interdisciplinary research and this has seldom involved working with natural scientists. All of these factors mean that, although the processes of globalization are accelerating, the necessary evolution of the social sciences to study these processes is not far advanced.

As a consequence, a high priority in research on the human dimensions of global environmental change must be placed on conceptual and methodological issues since, without appropriate concepts and methodologies, research cannot be undertaken. This challenge implies that concepts, theories, methods of observation and data collection, and models have to developed to consider global issues from a global perspective, both within individual social sciences and in interdisciplinary frameworks. In some cases, such frameworks will also involve adapting appropriate insights and techniques from natural sciences.

The necessity of adopting a global rather than a nation-state perspective to do research on the human dimensions of global environmental change may constitute the most fundamental challenge for the social sciences. Since the seventeenth century, the nation state has been the fundamental unit of social, economic, and political organization, and more frequently than not social scientists

have taken the nation state as the basic framework for organizing their studies and developing their positive, empirical, and normative theories. Global environmental change, however, is *global* and the framework for the analysis of the human dimensions must be global. While a start has been made, few of the social sciences have begun to take up this challenge.

A related issue concerns gaining competence in dealing with interactions between local and global and micro and macro phenomena. The facts that actions at the local level can cause global change which in turn will have differing effects in differing locales provide the point of departure for exploration of this issue. The problem extends far beyond this. For example, it is generally accepted that world-wide economic trends have serious and varied local consequences - consequences that contribute to behavior such as the destruction of rain forests that contribute to global environmental change - but the connections between the world-wide trends and individual and group behavior are seldom convincingly demonstrated. Social science is rich with local, national, and international and micro and macro studies, but the connections between the various levels have largely been unexplored. Research on the human dimensions of global environmental change will require that methodologies be developed for exploring these connections.

Issues concerning two primary elements of research are discussed below: preliminary exploration of relationships among variables and data collection and management. Although the two are discussed separately for the sake of clarity, the issues involved are closely linked, in practice they frequently must be dealt with simultaneously or iteratively rather than sequentially.

1. Preliminary exploration of relationships among variables

The first stage of research involves developing an initial understanding of the relevant phenomena and processes, through identification of the fundamental variables involved in a specific domain and their hypothetical links, starting from available knowledge and proceeding through the construction of hypotheses. Following this initial stage, the second stage involves the deepening of the understanding of relationships among the chosen variables. Given the systemic and interacting nature of the physical, chemical and biological processes of global environmental change, the establishment of significant linkages between these processes and particular sets

of human actions is a difficult task that will often require interdisciplinary cooperation.

Two general types of research strategy are often used for the purpose of gaining preliminary understanding of relationships among variables: one approach emphasizes induction, the other deduction. The two research strategies that have frequently been used are case studies and modelling, whether conceptual or, if appropriate, mathematically-based. These two strategies have typically been conducted independently, and particular disciplines tend to use one or the other. However, the demands of research on the human dimensions of global environmental change will frequently require that studies into a particular topic use both in a complementary manner.

The case study approach has a substantial advantage that is particularly important for research on the human dimensions of global environmental change. The advantage of case studies is that they involve detailed analyses, often utilizing field research. Case studies are frequently a necessary first step in deciphering the inner workings of a social process that contributes to global environmental change. Field research can be indispensable for identifying cultural norms, social relationships, power structures, and links between them, without the knowledge of which meaningful modelling cannot be undertaken. Multiple case studies may well be required to gain an initial understanding of changing patterns of land use, energy production and consumption, and industrial growth throughout the world.

The challenge of the case study approach is to develop methodologies by which case studies can be conducted efficiently and quickly and in such a way that they yield comparable results. For instance, this may mean that such parallel or cooperative research, while focussing on a specific issue at a specific location such as land use, identifies the various actors and their basic interests, the strategies and tactics they use, the real and apparent status of conflicts on the processes under study, fixed constraints (e.g. needs for food, warmth, and shelter), potential approaches for change and, possibly, steps that might be taken to bring about desired changes, respecting the dignity and independence of individuals, communities, and groups.

The modelling approach begins with the exploration of existing explanatory models of issues and processes that include relation-

ships that are similar or comparable to those under consideration. Following this initial stage, relevant mathematical or non-mathematical models may be revised in order to increase their utility for the research in question. Alternatively, as is particularly clear with respect to the social dimensions of resource use, new models may have to be developed from components of existing models and/or data-driven or theoretical approaches which appear valuable for increasing understanding of the relationships under consideration or from the results of a case study or a suite of comparative case studies. The sources of models might be found in any one, or a mixture, of natural and/or social science disciplines. The most commonly used mathematical models are sets of simultaneous equations that describe interactions between variables. Other types of models exist, or have been proposed, that involve stochastic processes, or are based on chaos theory. Variability can be introduced in mathematical models through the use of differing assumptions.

As noted above, a critical issue in the choice and evolution of suitable models will be the development of efficient communication and clear understanding between scientists from all involved disciplines and, in some cases, policy-makers.

Once a suitable model is in existence, it has to be validated against data which describe the variables and relationships under consideration. The analysis of these data may also indicate needs for improving and updating models. Thus, data collection methodologies must be explicitly designed to provide the information critical for validating, improving, and updating models. As discussed below, the design of such methodologies should be a significant part of the development of interdisciplinary and international research projects.

The broad relationship in social science research between induction and deduction and case studies and modeling is well known and clear. Unfortunately the task of relating case studies and models is complicated and probably for this reason the relationship is only infrequently established and properly utilized. Case studies may and usually should be guided by a deductively determined model and the results of a single case study or a suite of them can be used as the initial basis for the construction of a model and its subsequent refinement. The task is complicated among other reasons because case studies provide rich but often unsystematized detail while models require precise formulations of relatively limited numbers of relationships.

These problems that have hampered the effective integration of case studies and modeling will be compounded in efforts to study the human dimensions of global environmental change. Studies of the physical, chemical and biological processes involved in will often yield large-scale models of interactions; linking these models with human behavior will pose a fundamental challenge. They may be joined with comparative ease to demographic or macro-economic models, yet even in these cases daunting problems involving the compatibility of spatial and temporal scales will have to be overcome. The conundrums involved in linking models of physical, chemical, and biological process with case studies of human behavior at various levels have hardly been addressed, yet they must be explored and solutions found if the interaction between human and natural phenomena is truly to be understood.

2. Data collection and management

Research based on both case studies and modelling - techniques utilized for full as well as exploratory studies - and on other techniques and methodologies, including sample surveys and aggregate analyses, will involve the collation of existing data and the collection of new data. These data must be fitted together and, in many cases, joined with data resulting from research in the natural sciences. To understand and model social processes and the interaction between these and natural processes - an ambitious long-term goal of this research program - high-quality data are essential. Because of the necessity that research on the human dimensions of global environmental change be global in scope and the reality that it will be decentralized, arrangements must be made to ensure that data are readily and widely available.

Data which describe human activities and physical and biological systems are available for most parts of the biosphere. However, these data vary considerably in terms of their spatial scale, length of record, frequency of collection, replicability, and reliability - to name only a few parameters. To take a simple but critical example, while census data have been collected for some centuries in many industrialized countries, there are other countries whose population is still not known with great accuracy. Equally, while available data may be in computerized, geographically-referenced data bases, it is also highly likely that they remain on original survey forms or only as summary documents. Again, information drawn from case studies in different cultural settings, even if these studies

have a similar focus, may not be comparable and useful for research at a global scale unless they have been conducted according to carefully-designed methodologies.

The interdisciplinary and international research suggested by this Framework for Research will require the collation and collection of large volumes of data of all types - including administrative, census, governmental, and survey - by individuals working in many different disciplines and countries. In some cases, the requisite data may be available in suitable form for a specific research project. However, in many cases existing data will have to be reanalyzed, or made accessible, or new data will have to be collected. As mentioned previously, these and all subsequent activities will require efficient communication and clear understanding between scientists from all disciplines involved in the project.

As described in the discussion of research strategies for exploring preliminary relationships among variables, the range of variables must be decided early in the evolution of any research project. Steps must be taken to ensure that data are comparable and compatible. The issues involved in standardizing instruments utilized in cross-cultural and cross-national surveys are familiar to social scientists from many disciplines, though they are far from being solved. For further research in cross-cultural and cross-national settings, considerable methodological development is an essential prerequisite, especially where the comparative case study approach is utilized.

For interdisciplinary studies, two critical issues exist with regard to the compatibility of data concerning a variety of diverse variables and processes describing human and physical systems. The first concerns the spatial scale of the data and its mode of collection (e.g., uniformly over large areas or according to specific spatial sampling strategies). For example, how can atmospheric quality data collected from a number of stations be related to information on the areal distribution of fields of different crops and on the distribution and opinions of human populations in the same region? Such data are all collected by different means and describe interacting physical and human systems in different ways.

The second issue concerns the temporal scale of the data. Using the same example, the atmospheric quality data may have been collected every minute, but only for the past five years. These data may be aggregated over fixed time periods, and statistical dis-

tributions or frequencies of extreme events may or may not be available. The agricultural information is probably collected annually, but perhaps for twenty years. The census data are probably collected decadally, perhaps with annual estimates, but may be available for two centuries. Finally, the public opinion data are collected in sample surveys, which may take place regularly or irregularly. In all cases, another confounding factor is that methodologies, definitions, boundaries, and sampling points may well have changed during the period of record. The availability of records of these changes, or reasons for them, will determine whether reconciliation across the record is possible both within and between variables. In addition, if information derived from case studies is to be used in conjunction with these periodic data, it will be essential to establish its relevance both over the period of study and in terms of its cultural context.

In spite of these difficulties in acquiring compatible data, it is possible to undertake research utilizing historical data from a number of sources and disciplines. At the same time, it is critical that methodologies for the collection of new data be designed to minimize such problems. This applies both to the collection of data by traditional methods and by other methods made possible through disciplinary and interdisciplinary methodological evolution and evolving technologies. One of the most important of the latter is remote sensing, which allows standardized data sets to be collected at a great variety of temporal and spatial scales.

Remote sensing data may be collected from satellites, aircraft, or from the ground. The choice of sensing device(s) and frequency of data collection must be closely tailored to the purposes of a research project. At the same time, remotely-sensed information provides a historical record that can be reanalyzed for new information. Finally, in-situ sampling ("ground truthing"), to provide information on the accuracy of classification of images or data, must be an integral part of any project including remote sensing.

Geographic information systems (GIS) are a second important and evolving technology for interdisciplinary research. These allow data describing a great variety of variables to be stored in a georeferenced data base. These data can be drawn from remotely-sensed information, social science surveys, censuses, or any other type of source whose geographic location can be described. A GIS can be updated as new information becomes available, whether to increase the degree of detail available for a particular variable, or

to provide sequential information showing changes in the variable over time. The technology of GIS permits variables to be processed and analyzed in many ways, taking into account limitations to comparability. Outputs for dissemination during a project, and at its completion, can be designed for specific purposes (e.g. maps, graphs, or reports).

Since the conceptual and methodological development outlined above is essential to the completion of research and to understanding the human dimensions of global environmental change, it must be given priority. Work on these conceptual and methodological issues should precede and advance simultaneously with work on the substantive issues.

IV CHALLENGES FOR THE SOCIAL SCIENCES

The challenges of understanding the human dimensions of global environmental change are daunting, but the topic demands that the social sciences take up and meet these challenges.

It is broadly acknowledged that understanding the human dimensions of global environmental change is crucial for long-term sustainable use of the Earth's systems. Social science research is needed to explain how human beings contribute to global environmental change, the consequences of such change for human beings, and how they will respond. It is needed to illuminate the range of human choices in the face of global environmental change and the likely consequences of these choices for both human populations and the Earth's systems on which they depend.

In its report, *Our Common Future,* the World Commission on Environment and Development stated that sustainable development is "not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs." (p.9) To contribute to making sustainable development possible, the social sciences must, as they have in meeting past challenges, develop new theories and new methodologies transcending present scales of analysis and disciplinary boundaries. These will lead to new conceptions for innovative forms of social organization and types of action.

The challenges of global environmental change are not only daunting for the social sciences, they are likely to invigorate their future evolution. The vitalization of the social sciences will enhance their contribution to dealing with all social issues, not only those of global environmental change.

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